U.S. DEPARTMENT OF ENERGY | Nuclear Energy

U.S. DOE Nuclear Energy R&D Roadmap Overview

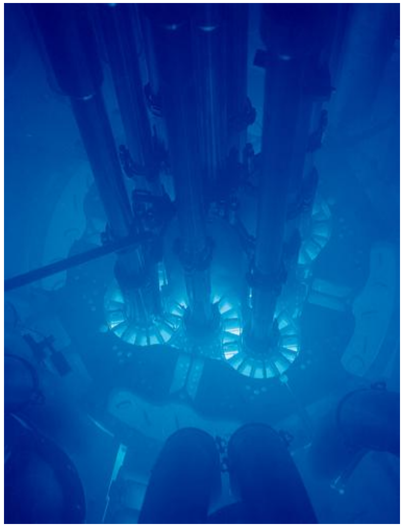
Warren "Pete" Miller

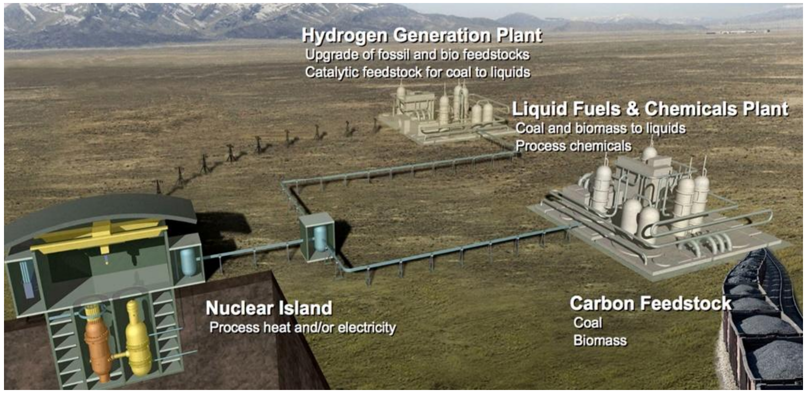
Assistant Secretary

For Nuclear Energy

U.S. Department of Energy

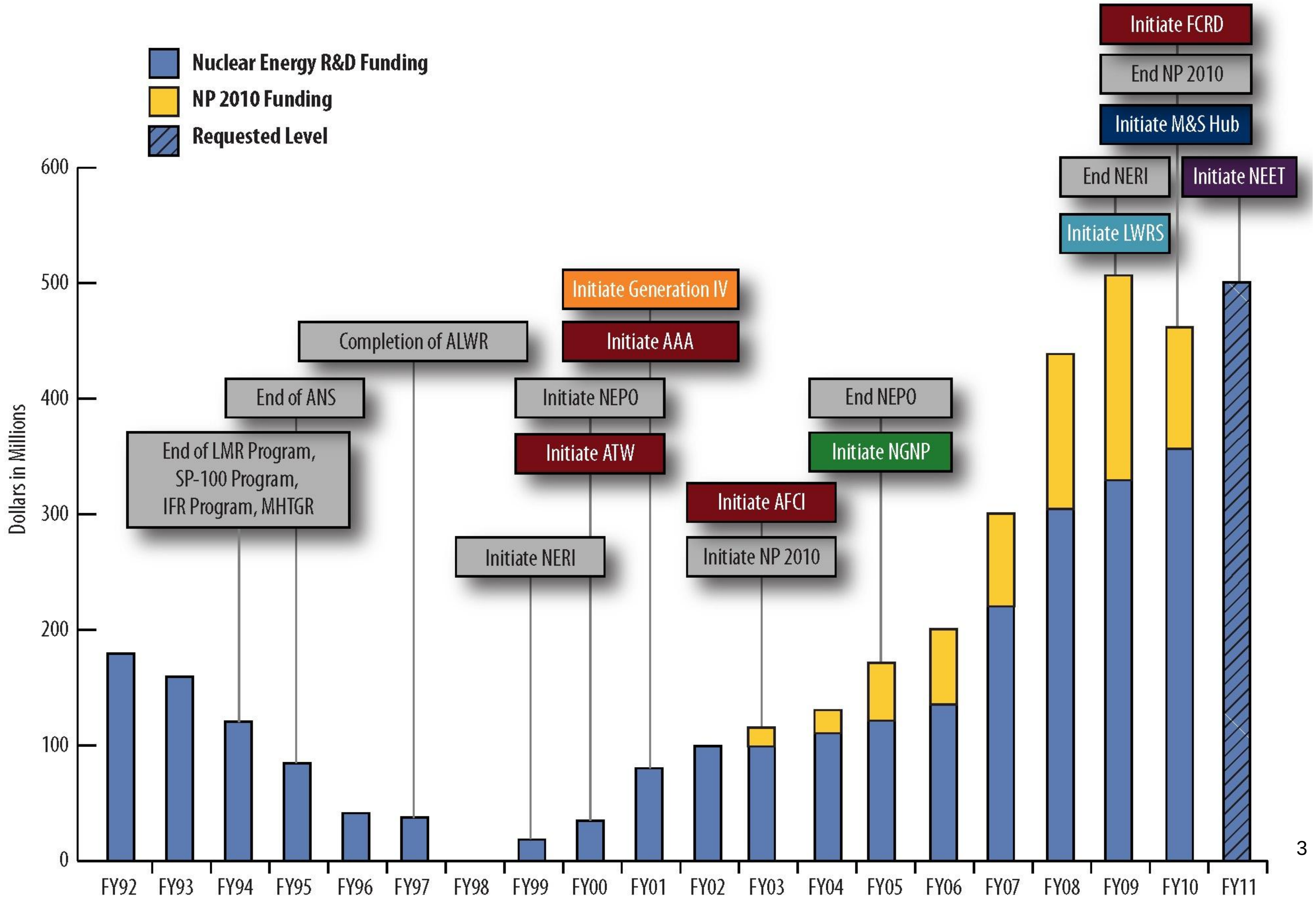
Office of Nuclear Energy Mission





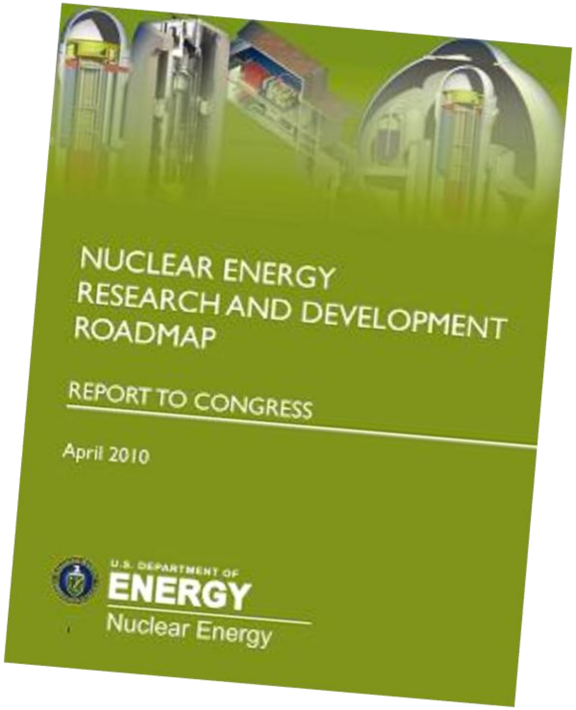
- **The primary mission of NE is to advance nuclear power as a resource capable of making major contributions in meeting the nation's energy supply, environmental, and energy security needs by resolving technical, cost, safety, security and regulatory issues, through research, development, and demonstration (RD&D).**
- **Objective is to enable the development and deployment of fission power systems for**
  - Production of electricity (MWh)
  - Process heat (BTUs)

Funding for Nuclear Energy Research and Development



Nuclear Energy Roadmap

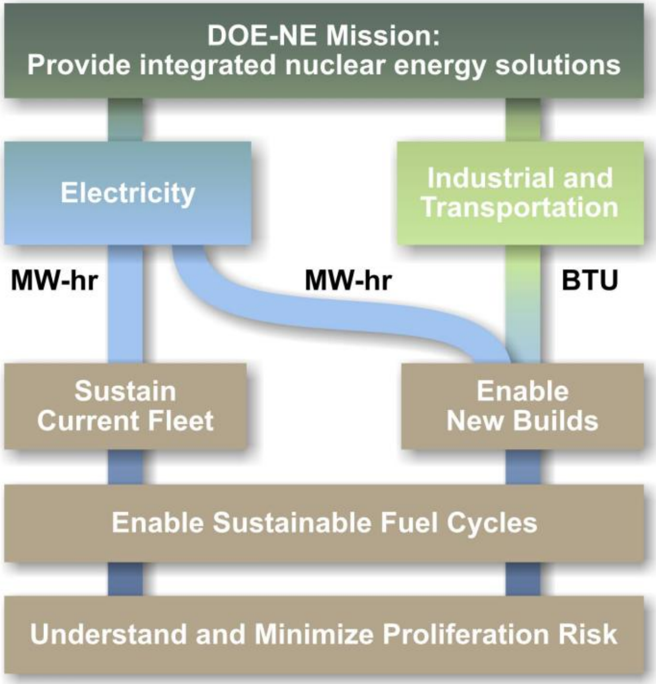
- **Nuclear energy objectives were developed to focus resources on national imperatives for clean energy, economic prosperity, and national security.**
- **Nuclear power will play an important role in helping to meet the nation's goals of energy security and GHG reductions.**
  - Studies have projected potential growth on the order of 50 to 100 GWe by 2030.



- **NE Roadmap outlines an integrated approach to meet objectives.**
- **Roadmap addresses transformation of NE programs to a more science-based approach.**

Nuclear Energy Objectives

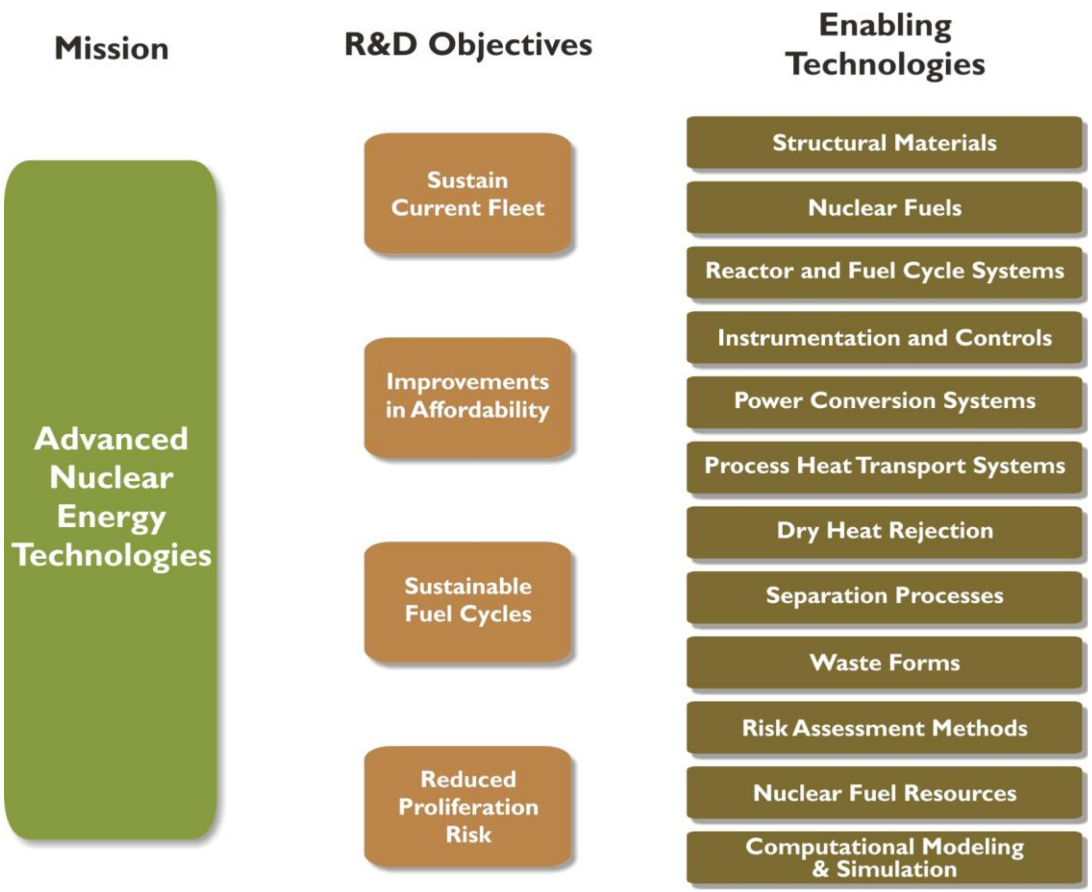
- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors
- Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals
- Develop sustainable nuclear fuel cycles
- Understand and minimize the risks of nuclear proliferation and terrorism



More detailed talks to follow – Reactor Analysis is included in all Objectives

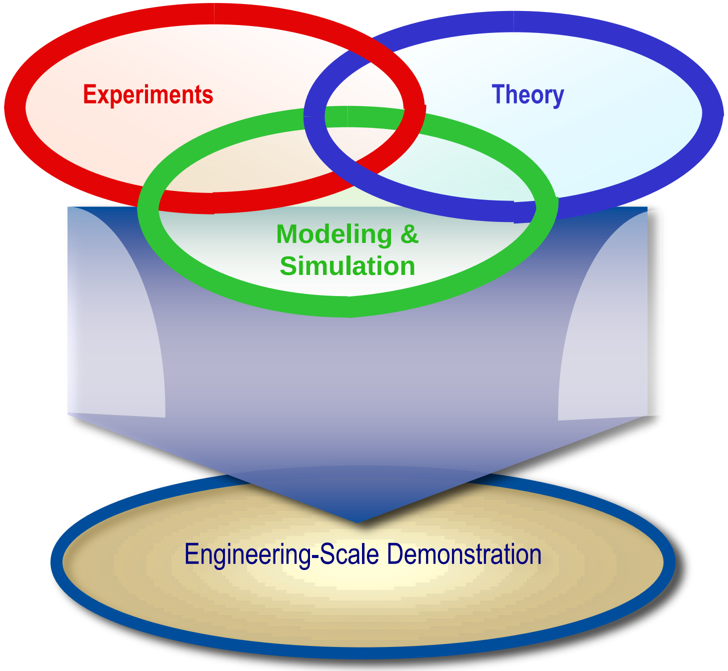
Nuclear Energy Research and Development

- **Roadmap is objective focused to enable advance nuclear technologies.**
- **Plan incorporates a portfolio of long-term R&D objectives and a balanced focus on evolutionary, innovative, and high-risk–high-payoff R&D in many diverse areas.**



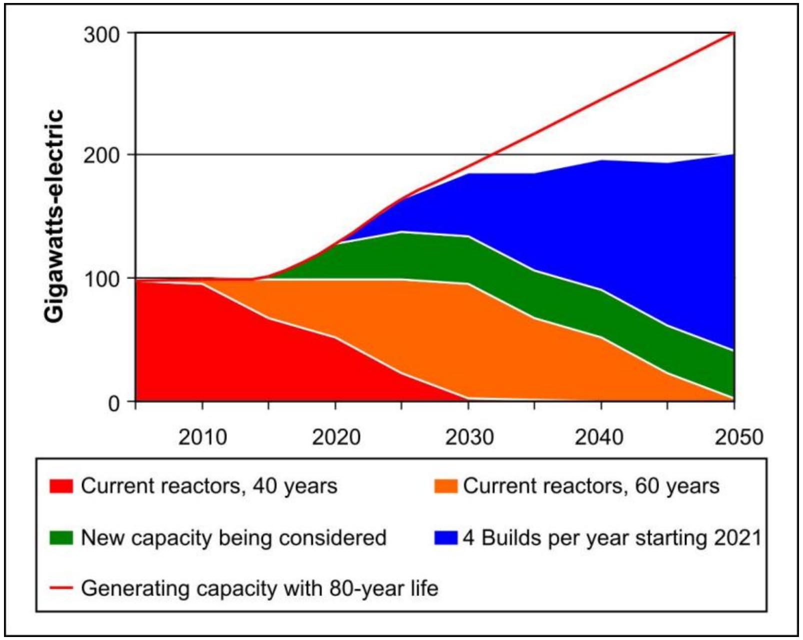
Science-Based Approach to Nuclear Energy Development

- **Experiments** – Physical tests to develop understanding of single effects or integrated system behaviors.
- **Theory** – Creation of models of physical behaviors based on understanding of fundamental scientific principals and/or experimental observations.
- **Modeling and Simulation** – Use of computational models to develop scientific understanding of the physical behaviors of systems. Also used to apply scientific understanding to predict the behavior of complex physical systems.
- **Demonstrations** – New technologies, regulatory frameworks, and business models integrated into first-of-kind system demonstrations that provide top-level validation of integrated system technical and financial performance.



Objective 1: Life Extension

- **Goal is to provide technical basis to extend plant life beyond 60 years with improved performance**
- **Challenges**
  - Aging and degradation of system structures and components
  - Fuel reliability and performance
  - Obsolete analog instrumentation and control technologies
  - Design and safety analysis tools based on 1980's vintage knowledge bases and computational capabilities



Objective 2: New Builds

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- **Goals**
  - Demonstrate 10 CFR Part 52 licensing framework
  - Facilitate accelerated licensing of small modular reactors
  - Facilitate development and demonstration of advanced manufacturing and construction technologies
  - Develop and demonstrate next generation advanced plant concepts and technologies

- **Challenges**
  - Financial hurdles associated with new plant
  - Deploy small reactors to reduce up front capital costs
  - Develop plant designs that address industrial needs
  - Uncertainty over new regulatory frameworks

New Builds to Support Transition from Fossil Fuels

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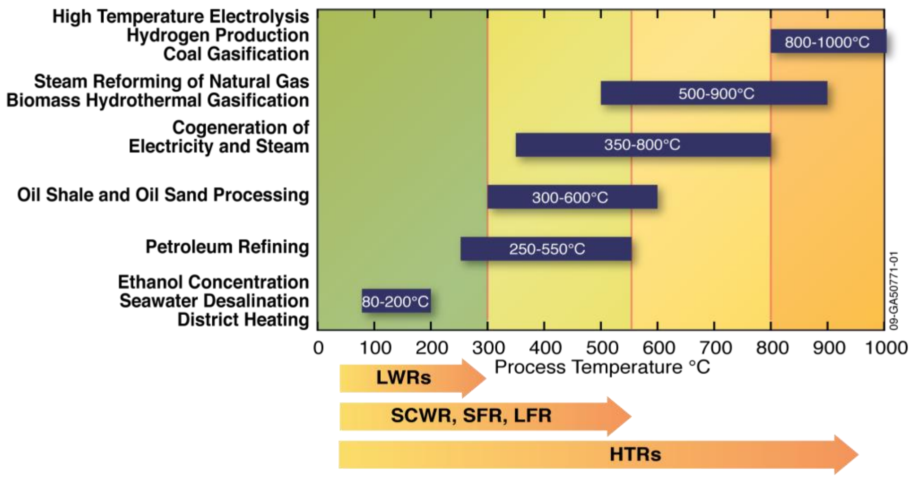
- **Goals**
  - Use existing technology to reduce greenhouse gas emission
  - Develop and qualify technologies to provide process heat
  - Develop interfacing systems for industrial and transportation sectors
  - Establish basis for licensing high temperature reactors

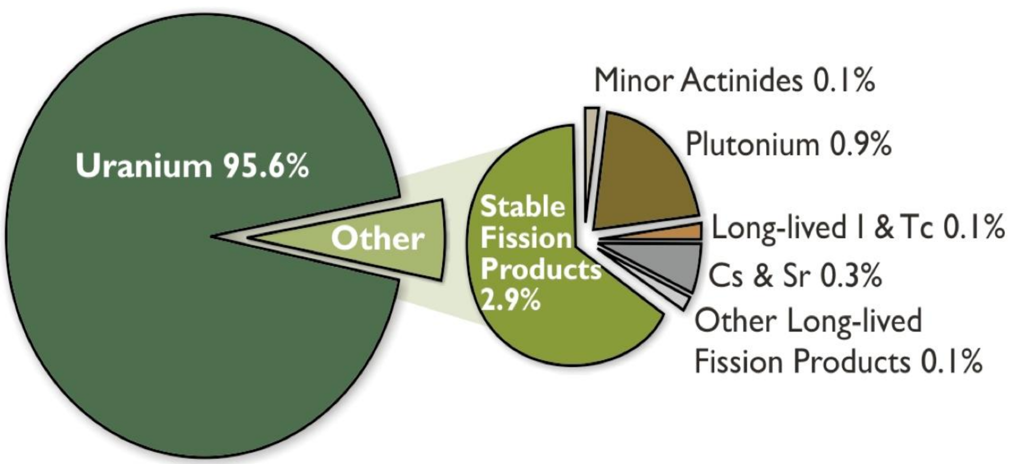


- **Challenges**
  - Providing process heat to industry will require: Higher temperature reactors, efficient heat transport systems, interface systems for control and isolation, and a robust licensing case.
  - Institutional differences exist between transportation, industrial, and electric power sectors.
  - High temperature reactors will generate used fuels that have a different composition from what current LWRs produce.

Objective 3: Sustainable Fuel Cycles

- **Goals**
  - In the near term, define and analyze fuel cycle technologies to develop options that increase the sustainability of nuclear energy
  - In the medium term, select preferred fuel cycle option for further development
  - By 2050, deploy preferred fuel cycle

- **Challenges**
  - Develop high burnup fuel and structural materials to withstand irradiation for longer periods of time
  - Develop simplified separations, waste management, and proliferation risk reduction methods
  - Develop optimized systems to maximize energy production while minimizing waste



Bases for Fuel Cycle Research and Development Program (FCRD)

- **Dry cask storage is safe, and used nuclear fuel can be stored for many decades.**
  - R&D includes work on long-term storage.
- **From safety perspective, there is not an urgency to implement a final fuel cycle.**
  - There is time to pursue R&D to assess better approaches.
- **The once-through fuel cycle is the baseline.**
  - Options will be evaluated against the baseline.
  - Final choice may include both once-through and reprocessing.
- **At least one repository will be needed for all options.**
- **Blue Ribbon Commission will provide recommendations that will guide FCRD.**

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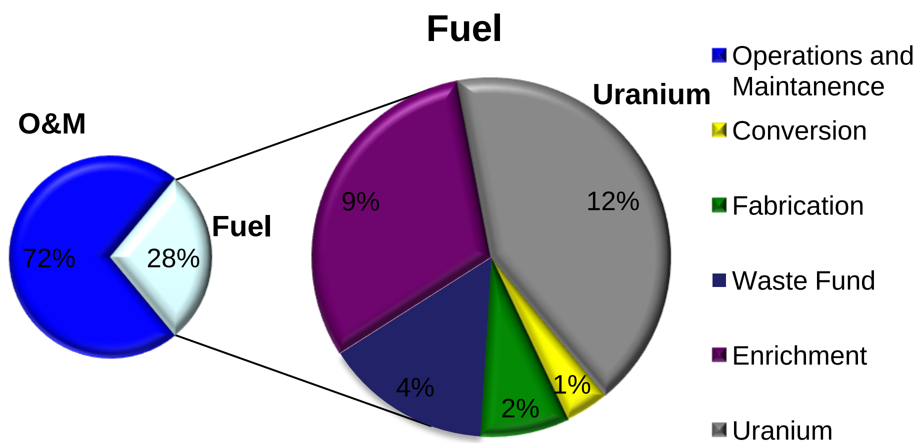
Issues Impacting Choices

- Technology readiness
- Costs of reactor systems
- Availability/costs of uranium
- Repository issues (capacity, availability, costs, geological media, etc.)
- Proliferation risks
- Social issues (intergenerational equity, resource stewardship, repository siting, etc.)
- Etc.

Contributions to the Costs of Electricity from Operating Nuclear Power Plants

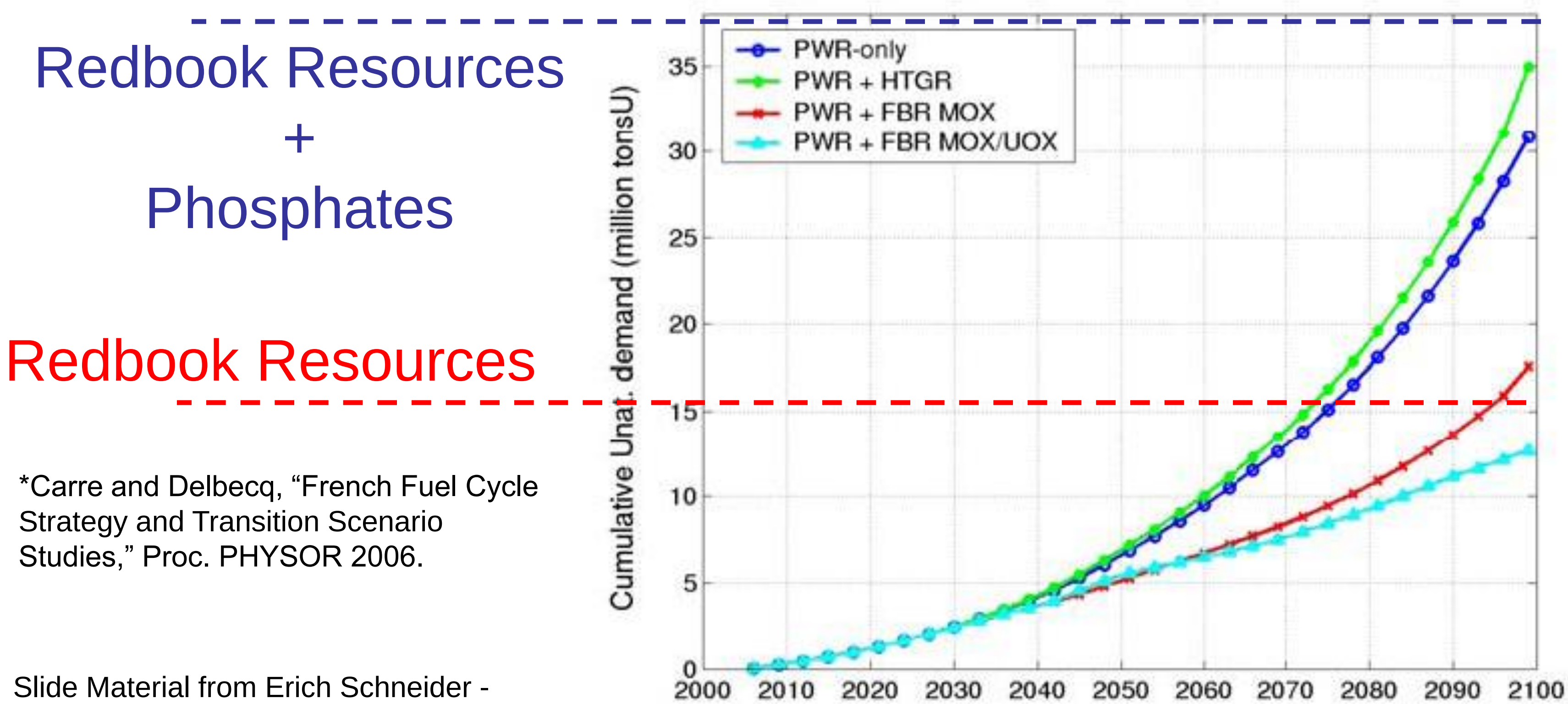


•Average cost of operating plants is approximately 2 cents per kilowatt-hour (NEI).
•Uranium cost will be a smaller fraction of new plants costs.

Source: Ventyx Velocity Suite; Energy Resources International via NEI

Uranium Requirements Through 2100

The figure* presents cumulative **world** uranium consumption for scenarios ranging from once through (30-35 million tons) to a transition to breeders beginning in 2040 (13 million tons).

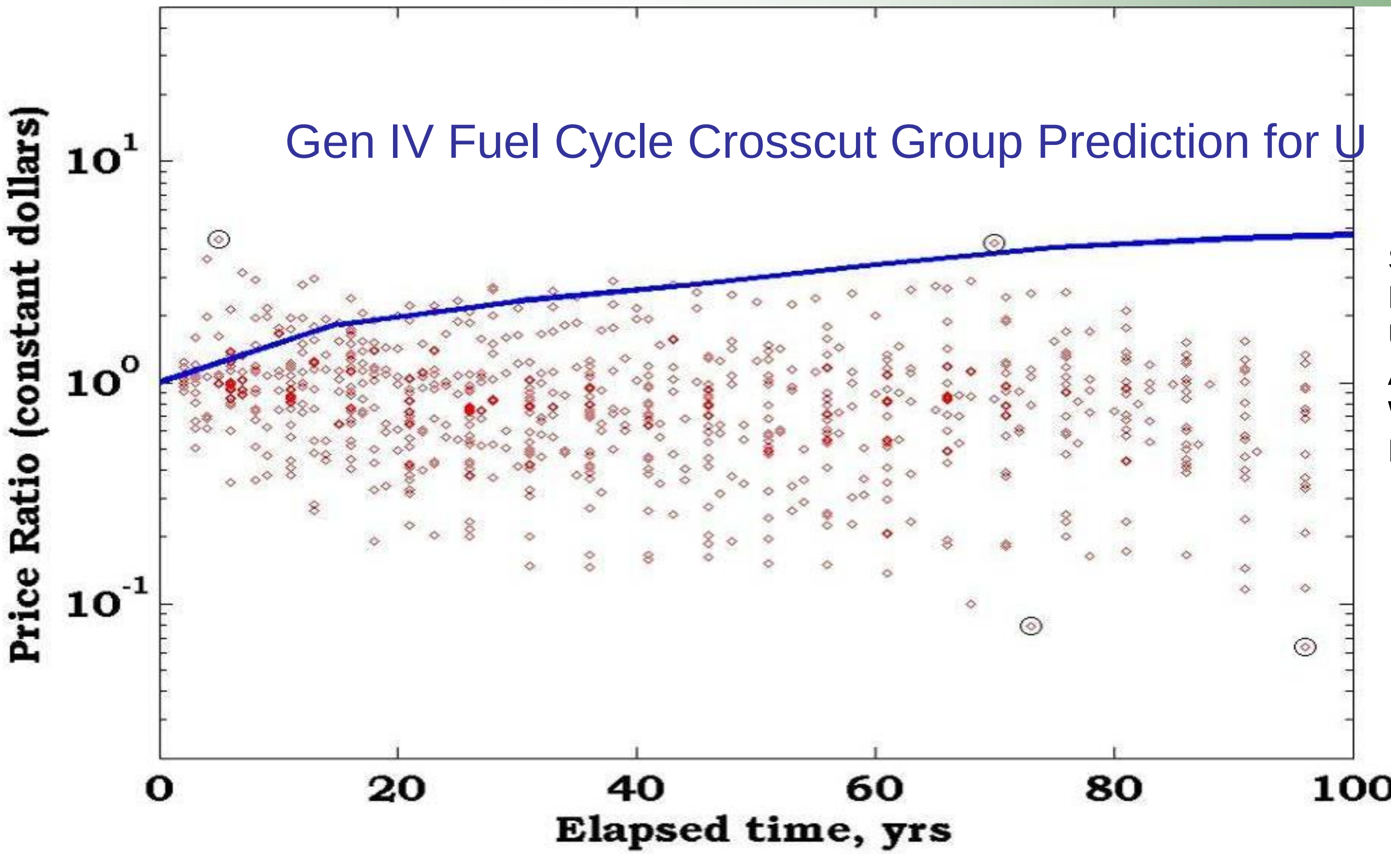


World nuclear power demand obtained from WEC/IIASA “Global Energy Perspectives” A-3 Scenario.

*Carre and Delbecq, “French Fuel Cycle Strategy and Transition Scenario Studies,” Proc. PHYSOR 2006.

Slide Material from Erich Schneider - University of Texas, ANTT Meeting, Washington, DC, February 19, 2009

Price For Many (34) Minerals vs. Time…



Slide Material from Erich Schneider - University of Texas, ANTT Meeting, Washington, DC, February 19, 2009

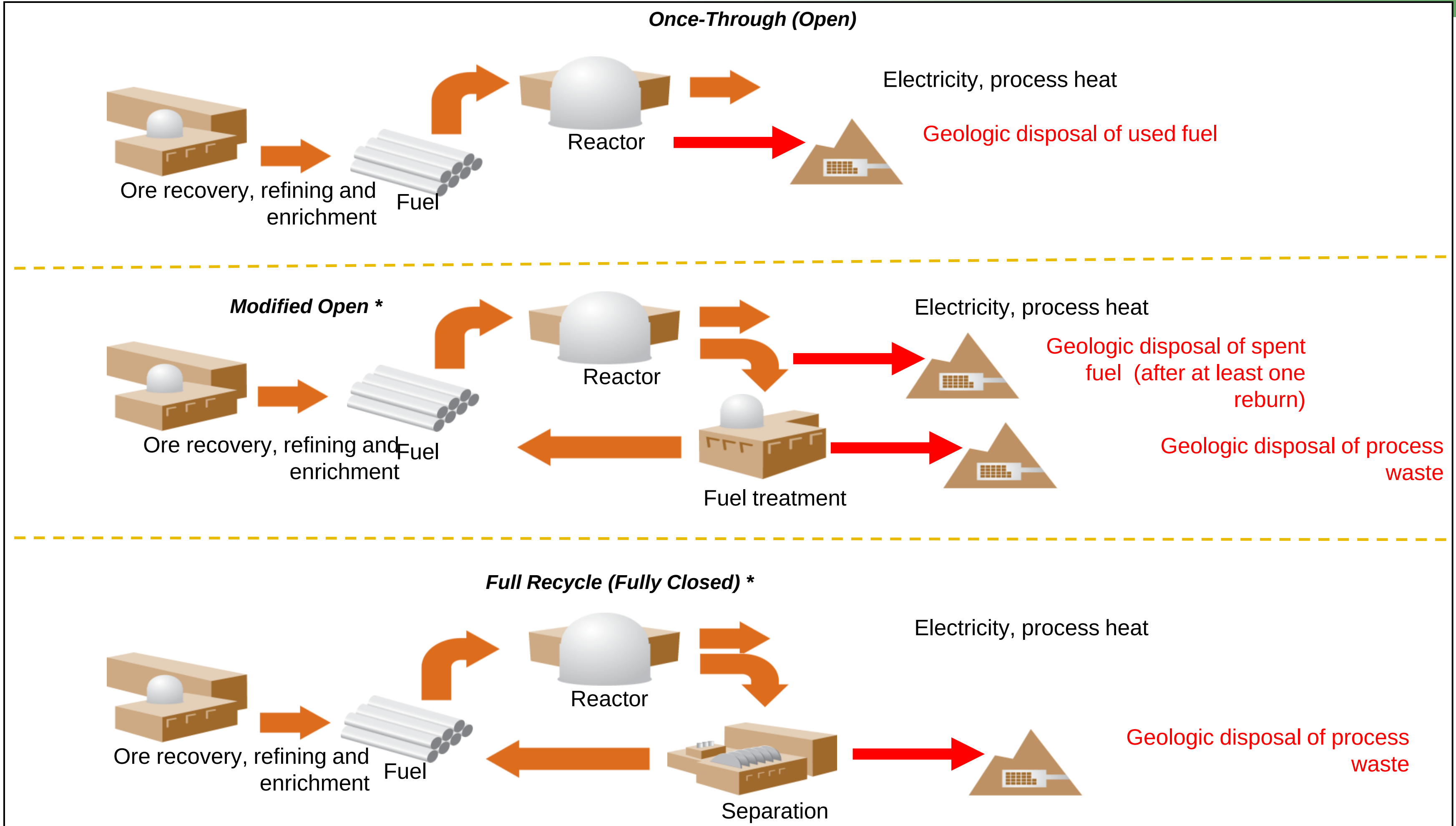
US Geologic Survey data. Price Ratio = current price of the mineral divided by price of the mineral in year 1 (1900 or first year data are available).

Mineral prices have dropped over the past century.

Three Potential Fuel Cycle Options

- **Once-Through**
  - No recycling or conditioning of used fuel
  - Low uranium utilization
  - Appropriate for a low price uranium future
  - Appropriate when repository capacity and/or actinide loadings are not show stoppers
- **Full Recycle**
  - Multiple reprocessing steps and transmutation of actinides
  - “Complete” uranium utilization (with breeder)
  - Appropriate for high price uranium future
  - Appropriate when repository capacity and/or actinide loadings are show stoppers
- **Modified Open Cycle**
  - Very limited used fuel conditioning or processing (e.g., recladding)
  - High uranium utilization and burnup (i.e., used fuel is spent fuel)
  - Appropriate for a high price uranium future or intent to better utilize domestic resources
  - Appropriate when major constraint is on repository capacity (e.g., heat loading, geologic media)
  - Appropriate when actinide loading is not a show stopper

Three Potential Fuel Cycle Options (cont'd)



*A specific fuel cycle strategy may include more than one fuel design, reactor design, or fuel treatment process.

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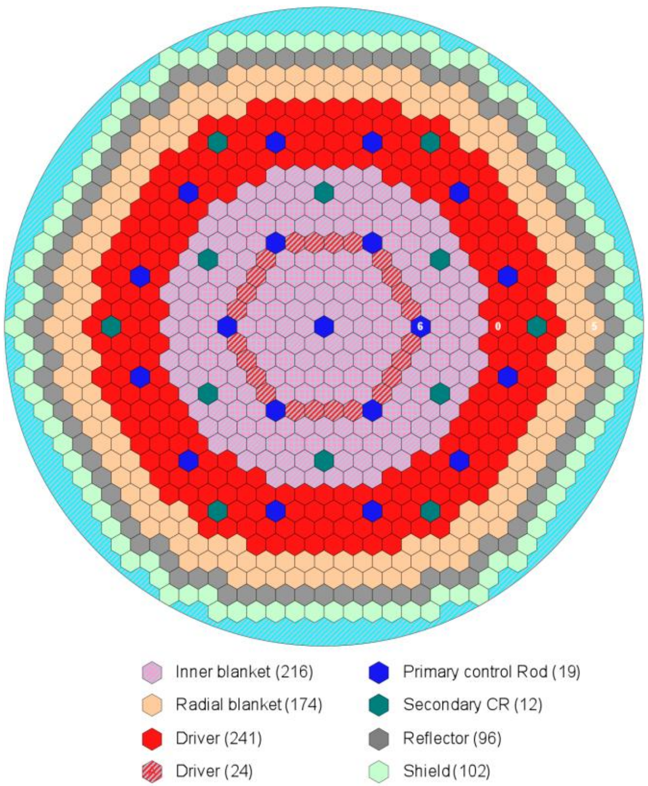
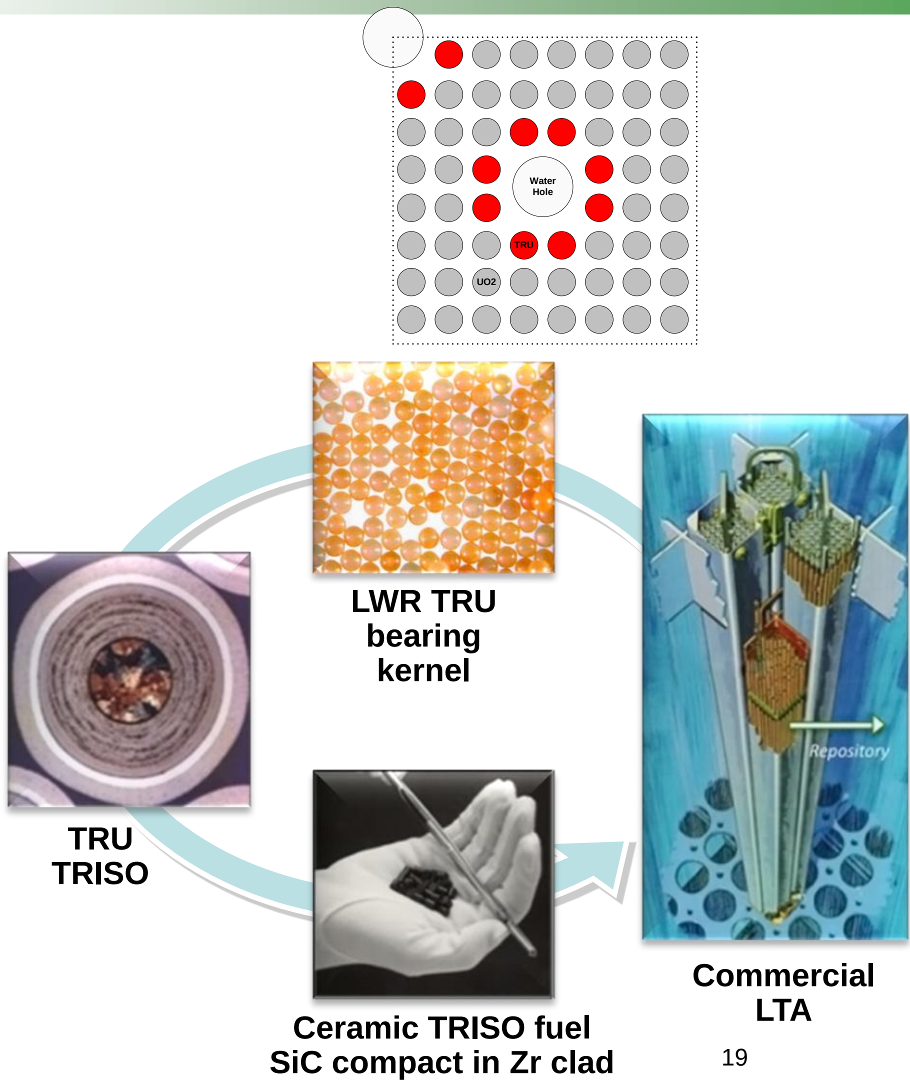
Example Modified Open Cycle - Breed and Burn Reactor



- **Breed and burn systems are proposed to potentially increase uranium utilization without significant reprocessing.**
- **Concepts employ large blankets to breed fissile material, and driver regions to provide initial power with the bred material gradually taking over.**
- **Concepts are typically based on fast neutron reactors.**
- **They may have long core-life (40+ years).**
- **Limited separations processes, like melt refining, may be employed to increase uranium utilization.**
- **Challenges include**
  - Very large cores and possible costs
  - High burnup and high fluence fuels
  - Operational issues due to core configuration
  - End of life materials management

Example Modified Open Cycle – Deep Burn

- Deep Burn concept is exploring the feasibility of SiC-matrix TRISO fuel to burn transuranics.
- Materials could potentially be burned in existing LWRs or high-temperature gas reactors.
- Fuel from existing LWRs would be reprocessed to recover the transuranics for burning.
- Deep burn will result in some increase in uranium utilization, but total utilization is still low.
- Challenges include
  - High burnup fuels
  - End of life materials management



Objective 4: Understand and Minimize Proliferation Risk

- **Goal is limiting proliferation and security threats by protecting materials, facilities, sensitive technologies and expertise.**

- **Challenges**
  – Develop proliferation risk assessment methodologies and tools
  – Minimize potential for misuse of technology and materials
  – Develop highly reliable, remote, and unattended monitoring technologies
  – Design improved safeguards into new energy systems and fuel cycle facilities
  – Develop advanced material tracking methodologies

Concluding Comments

- DOE is working toward an orderly shutdown of the Office of Civilian Radioactive Waste Management.
- DOE-NE absorbs the core responsibility for the technical work associated with implementation of the Nuclear Waste Policy Act.
- Blue Ribbon Commission recommendations will influence U.S. policy, and any corresponding changes in programmatic direction will influence Nuclear Energy Roadmap.
- DOE-NE stands ready to provide requested support to the Blue Ribbon Commission.